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(54) [TITLE OF THE INVENTION] ELECTRON EMITTING DEVICE,
ELECTRON SOURCE AND IMAGE FORMING APPARATUS

(57) [ABSTRACT]

[OBJECT] To provide an electron emitting device having high electrical resistance, good stability and high electron emission efficiency during driving, an electron source and an image forming apparatus.

[CONSTITUTION] A surface conductive type electron emitting device comprises a pair of opposing device electrodes 5 and 6 formed on a substrate, and a thin film 4 having an electron emitting portion 3.

The thin film 4 having the electron emitting portion 3

contains conductive fine particles and graphite, or/and amorphous carbons. An electron source includes a plurality of such electron emitting devices disposed on a substrate. An image forming apparatus uses the electron source.

[WHAT IS CLAIMED IS:]

[Claim 1] A surface conductive type electron emitting device comprising:

a pair of opposing device electrodes formed on a substrate; and

a thin film having an electron emitting portion,

characterized in that the thin film having the electron emitting portion contains conductive fine particles and graphite, or/and amorphous carbons.

[Claim 2] An electron emitting device according to claim 1, characterized in that the conductive fine particles are metal, alternatively metal oxide.

[Claim 3] An electron emitting device according to one of claims 1 and 2, characterized in that the conductive fine particles are palladium, alternatively palladium oxide.

[Claim 4] A manufacturing method of a surface conductive type electron emitting device, which comprises a pair of opposing device electrodes formed on a substrate, and a thin film having an electron emitting portion, comprising at least the steps of:

forming the pair of device electrodes;

forming the thin film for forming the electron emitting portion; and

performing a forming operation.

[Claim 5] A manufacturing method of an electron emitting device according to claim 4, characterized in that the pair of device electrodes are formed after the thin film for forming the electron emitting portion provided on the substrate is first formed, and then the forming operation is executed.

[Claim 6] A manufacturing method of an electron emitting device according to one of claims 4 and 5, characterized in that in the step of forming the thin film for forming the electron emitting portion comprising, forming the thin film made of a high molecular compound having metal, metal oxide, alternatively an organometallic compound dispersed therein, and then the thin film made of the high molecular compound is subjected to baking at a temperature of 600 °C to 3000 °C.

[Claim 7] A manufacturing method of an electron emitting device

according to claim 6, characterized in that the high molecular compound is polyimide.

[Claim 8] A manufacturing method of an electron emitting device according to claim 6, characterized in that the metal, alternatively the metal oxide, is one selected from palladium and palladium oxide.

[Claim 9] A manufacturing method of an electron emitting device according to claim 6, characterized in that the baking at the temperature of 600 °C to 3000 °C is executed in nitrogen atmosphere.

[Claim 10] A manufacturing method of an electron emitting device according to claim 6, characterized in that the baking at the temperature of 600 °C to 3000 °C is executed for 10 minutes to 2 hours.

[Claim 11] An electron source for emitting electrons according to an input signal, comprising:

a plurality of electron emitting devices specified in claim 1, which are disposed on a substrate.

[Claim 12] An electron source according to claim 11, further comprising: a plurality of columns made of groups of electron emitting devices, the plurality of electron emitting devices being disposed in parallel on the substrate, and both ends of each of the devices being connected to a wiring; and modulating means.

[Claim 13] An electron source according to claim 11, characterized in that one, alternatively more X-direction wirings, and one, alternatively more Y-direction wirings, electrically insulated from each other, are formed on the substrate, the Y-direction wirings being disposed in directions different from those of the X-direction wirings, and the plurality of electron emitting devices are arrayed in a manner that one of a pair of device electrodes of each device is connected to the X-direction wiring, and the other is connected to the Y-direction wiring.

[Claim 14] An image forming apparatus for forming an image based on an input signal, comprising at least:

an image forming member; and

the electron source specified in claim 11.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of Industrial Application] The present invention relates to an

electron source, and an image forming apparatus such as a display device or the like, to which the electron source is applied. More particularly, the invention relates to a surface conductive type electron emitting device having a novel configuration, an electron source, and an image forming apparatus such as a display device or the like, to which the electron source is applied.

[0002]

[Background Art] Conventionally, two kinds of electron emitting devices, i.e., a thermionic cathode electron source and cold cathode electron source, have been known. As the cold cathode electron source, a field emission type (abbreviated to FE, hereinafter), a metal/insulating layer/metal type (abbreviated to MIM, hereinafter), a surface conductive type electron emitting device (abbreviated to SCE, hereinafter), and so on, are available.

[0003] As examples of the FE type, those described in "Field emission" by W. P. Dyke & W. W. Dolan, p. 89, Advance in Electron Physics, Vol. 8 (1956), "Physical properties of thin-film field emission cathodes with molybdenum cones" by C. A. Spindt, p. 5248, J. Appl. Phys., Vol. 47 (1976), and so on, have been known.

[0004] As examples of the MIM type, those described in "The tunnel-emission amplifier" by C. A. Mead, p. 646, J. Appl. Phys., Vol. 32 (1961), and so on, have been known.

[0005] As examples of the SCE type, those described in "Radio Eng. Electron Phys." by M. I. Elinson, 10 (1965), and so on, have been known. The SCE type uses the phenomenon of electron emission caused by supplying a current in parallel with the surface of the thin film, which formed in a small area on the substrate. As materials to be used for the thin film, an SnO_2 thin film by M. I. Elinson and et al., an Au thin film [G. Dittmer: "Thin Solid Films", p. 317, Vol. 9 (1972)], an $\text{In}_2\text{O}_3/\text{SnO}_2$ thin film [M. Hartwell and C. G. Fonstad: "IEEE Trans. Ed Conf.", 519 (1975)], Carbon Thin Film [H. Araki and et al., Vacuum, p. 22, No. 1, Vol. 26 (1983)], and so on, have been reported.

[0006] As a typical example of the SCE type, the configuration of the device by M. Hartwell is shown in Fig. 15. In the drawing, a reference numeral 1 denotes an insulating substrate; and 2 a thin film for forming an electron emitting portion, which is made of a metal oxide thin film formed

by sputtering performed on an H-shaped pattern. An electron emitting portion 3 is formed by later-described energizing processing called FORMING. In the drawing, L_1 is set at 0.5 to 1 mm, and W_1 is set at 0.1 mm.

[0007] The FORMING is carried out to form the electron emitting portion 3 placed in the state of a high electrical resistance by applying, for energizing processing, DC voltage or very slow boosted voltages, e.g., 1 V/min., to both ends of the thin film 2 for forming the electron emitting portion 3 so as to locally fracture, deform or alter the thin film 2 for forming the electron emitting portion 3.

[0008] Thus, the electron emitting portion 3 means a portion where a fissure occurs partially in the thin film 2 for forming the electron emitting portion, and electrons are emitted from near the fissure. Hereinafter, the electron emitting portion forming thin film 2 including the electron emitting portion 3 formed by FORMING is referred to as a thin film 4 including the electron emitting portion.

[0009] The SCE subjected to the forming operation is adapted to apply a voltage to the thin film 4 including the electron emitting portion, and emit electrons from the electron emitting portion 3 by supplying a current to the device. Because of its simple structure and easy manufacturing, such an SCE is advantageous in that a number of devices can be arrayed and formed in a large area. As an example having a number of such SCE arrayed, there is an electron source, which is constructed in a manner that SCE are arrayed in parallel, and a number of rows connecting both ends of individual devices to wirings are arrayed (e.g., Japanese Patent Laid-Open Hei 1 (1989) - 031332).

[0010] As a specific application example of the electron source having a number of such SCE arrayed, there is a display device. Regarding the trend of the display device, in recent years, a planar display device using a liquid crystal has replaced a CRT in popularity. However, since it is not an emissive type, problems including the necessity of a backlight, and so on, have arisen. Therefore, the development of the display device of an emissive type capable of obtaining a high definition display image has been demanded.

[0011] In order to meet such a demand, an image forming apparatus has

been presented as a display device, which uses in combination the electron source having a number of SCE arrayed and a phosphor emitting visible lights by electrons emitted from the electron source. This apparatus can be manufactured relatively easily even if it has a large screen, and considered to be an emissive type having high display definition (e.g., US Patent No. 5066883).

[0012] Conventionally, in the display device including a number of SCE, the selection of a device for causing light emitting has been made based on driving signals properly supplied to a wiring connecting a number of SCE in one direction (referred to as row-direction wiring), a column-direction wiring connecting the same in a direction orthogonal to the row-direction wiring (referred to as a column direction) and a control electrode (referred to as a grid) installed in a space between the SCE and the fluorescent substance disposed above the SCE in non-contact therewith. An example of such a device is disclosed in Japanese Patent Laid-Open Hei 1 (1989) - 283749.

[0013]

[Problems to be Solved by the Invention] In order to put the SCE to practical use, apparently, improvements must be made on a stable and controlled electron emission characteristic and electron emission efficiency. The efficiency in this case means a current ratio between a current caused to flow (referred to as a device current I_f , hereinafter) and a current emitted into vacuum (referred to as an electron emission current I_e , hereinafter) when voltages are applied to a pair of device electrodes of the SCE. Preferably, the device current should be as small as possible, and the electron emission current should be as large as possible.

[0014] If the stable and controlled electron emission characteristic and the electron emission efficiency are improved, for example, for an image forming apparatus using the fluorescent substance as an image forming member, a bright and high definition image forming apparatus with a low current, e.g., a flat television set, is realized. In addition, with a lower current, it can be expected that a driving circuit, and so on, constituting the image forming apparatus will also be reduced in costs.

[0015] To make the SCE having such a stable and efficient electron emission characteristic, it is required that the device current I_f and the

electron emission current I_e should be maintained stable during driving. However, such stability depends on the structure of the electron emitting portion, and especially electrical resistance for preventing a structural change caused by the device current is required.

[0016] The present invention was made to solve the foregoing problems, and an object of the invention are to provide a novel configuration and a manufacturing method of an SCE having high electrical resistance, and hence having good stability and high electron emission efficiency. Other objects of the invention are to provide an electron source using such an SCE, and an image forming apparatus.

[0017]

[Means for Solving the Problems] Specifically, according to an aspect of the invention, a surface conductive type electron emitting device comprises: a pair of opposing device electrodes formed on a substrate; and a thin film having an electron emitting portion. In this case, the thin film having the electron emitting portion contains conductive fine particles and graphite, or/and amorphous carbons.

[0018] According to another aspect of the invention, a manufacturing method of a surface conductive type electron emitting device, which comprises a pair of opposing device electrodes formed on a substrate, and a thin film having an electron emitting portion, comprises at least the steps of: forming the pair of device electrodes; forming a thin film for forming the electron emitting portion; and performing a forming operation.

[0019] According to yet another aspect of the invention, an electron source for emitting electrons according to an input signal comprises: a plurality of above-described electron emitting devices disposed on a substrate. According to a further aspect of the invention, an image forming apparatus for forming an image based on an input signal comprises at least: an image forming member; and the above-described electron source.

[0020] Next, the present invention will be described in detail. The surface conductive type electron emitting device of the invention comprises: a pair of opposing device electrodes formed on a substrate; and a thin film having an electron emitting portion. In this case, the thin film for forming the electron emitting portion contains conductive fine particles and graphite, alternatively amorphous carbons, otherwise a mixture thereof.

[0021] The manufacturing method of such an electron emitting device comprises at least the steps of: forming a thin film having an electron emitting portion; forming a pair of device electrodes; and performing a forming operation. In this case, the step of forming a thin film for forming the electron emitting portion comprising, a thin film made of a high molecular compound having metal, metal oxide or an organometallic metal compound dispersed therein is formed, and then the thin film made of the high molecular compound is subjected to baking at a temperature of 600 to 3000 °C for 10 min. to 3 hours.

[0022] The electron source for emitting electrons according to an input signal comprises: a plurality of above-described electron emitting devices disposed on a substrate. Specifically, this electron source is arranged in a manner that a plurality of electron emitting devices are disposed in parallel on the substrate, a plurality of groups of electron emitting devices are provided, both ends of each electron emitting device being connected to wirings, and further modulating means is provided for each device. Alternatively, the electron source is arranged in a manner that a plurality of X-direction wirings and a plurality of Y-direction wirings, electrically insulated from each other, are installed on the substrate, the Y-wirings being disposed in directions crossing the X-direction wirings, an electron emitting device is disposed for each crossing point between the X-direction and Y-direction wirings, and one of a pair of device electrodes of each device is connected to the X-direction wiring, and the other is connected to the Y-direction wiring.

[0023] The image forming apparatus for forming an image based on an input signal comprises at least: an image forming member made of a fluorescent substance or the like; and the above-described electron source.

[0024] Next, the basic configuration and the manufacturing method of the SCE of the invention will be described. Figs. 1(a) and 1(b) are plan and sectional views showing the basic configuration of the SCE of the invention. Fig. 2 is a view showing an exemplary of manufacturing method of the SCE.

[0025] Now, description will be made of the basic configuration of the electron emitting device and the manufacturing method thereof according to the invention by referring to Figs. 1 and 2. In these drawings, a reference numeral 1 denotes an insulating substrate; 2 a thin form for forming an

electron emitting portion; 3 an electron emitting portion; 4 a thin film including the electron emitting portion; and 5 and 6 device electrodes.

[0026] For the insulating substrate 1, a glass substrate prepared by laminating quartz glass, glass having a reduced content of impurities such as Na, soda lime glass and an SiO_2 formed on the soda lime glass by sputtering or the like, ceramics such as alumina, and so on, can be used. As described later, however, since a heat treatment at a temperature of 600 to 3000 °C is necessary in the device manufacturing process of the invention, a substrate material having heat resistance must be used. From this viewpoint, the use of especially quartz, silicon, alumina, and so on, is preferred.

[0027] After the substrate 1 is sufficiently cleaned by detergent, pure water and organic solvents, the thin film 2 for forming an electron emitting portion is formed on the substrate 1 (See Fig. 2(a)). For example, a thin film is formed, which is made of a high molecular compound containing a metal, such as Pd, Ru, Ag, Au, Ti, In, Cu, Cr, Fe, Zn, Sn, Ta, W, Pb, and so on. Then, this thin film is subjected to baking at a temperature of 600 °C or higher, and a thin film is formed, which contains the above metals or oxides thereof, and amorphous carbons or graphite or a mixture thereof. As occasion demands, this thin film is subjected to patterning by using a photolithography technology, and thus the thin film 2 for forming the electron emitting portion is formed.

[0028] The specific examples of materials for the thin film 2 for forming the electron emitting portion are amorphous carbons or graphite or mixture thereof including metals of Pd, Ru, Ag, Au, Ti, In, Cu, Cr, Fe, Zn, Sn, Ta, W, Pb, and so on, or amorphous carbons or graphite or mixture thereof including metal oxides of PdO , SnO_2 , In_2O_3 , PbO , Sb_2O_3 , and so on. The metals or the metal oxides may be in fine particulate forms. In other words, the thin film 2 for forming the electron emitting portion is made of amorphous carbons or graphite containing the metals or the metal oxides in particulate forms. The particle diameter sizes of such fine particles should be set in the range of several Å to several thousand Å, preferably in the range of 10 to 200 Å. Among these metals or metal oxides, the use of especially Pd or PdO_2 is preferred from the viewpoint of an electron emission characteristic.

[0029] The amorphous carbons or graphite used in this case are obtained by baking the high molecular compound at a temperature of 600 to 3000 °C. Accordingly, first, a mixture containing the metals and the high molecular compound, or the metal oxides and the high molecular compound is deposited on the substrate 1. For the method of deposition, one can be selected from conventionally known methods, e.g., a rotational coating method, a dipping method, a printing method, Langmuir-Blodgett (abbreviated to LB, hereinafter) method, and so on. The invention places no limitation on the method of deposition. However, because of good uniformity of a deposited film, the use of the LB method is preferably. The details of the LB method will be described later.

[0030] Then, after the baking of the film at the above-described temperature (600 to 3000 °C), the thin film 2 for forming the electron emitting portion can be formed, which is made of amorphous carbons or graphite, and including the metals or the metal oxides in particulate forms. In this case, as a material to be mixed with the high molecular compound, in addition to a single metal or oxide among the foregoing, an organometallic compound (complex) containing such metals can be used. This is because an organic portion included in the organometallic compound is desorbed or sublimated during baking, and thus the metal or the metal compound (if baking is carried out in oxygen atmosphere, a metal oxide may be formed as a result of metal oxidation) is left. A high molecular compound mixing a single metal or metal oxide or an organometallic compound is referred to as a high molecular compound containing metals, hereinafter.

[0031] Apparently, the formation of the thin film 2 for forming the electron emitting portion as uniform as possible is important for a device characteristic. Specifically, it is important that metal elements (single metal or metal oxide), and amorphous carbons or graphite should not be in extremely flocculated states (macro phase separation) but in sufficiently dispersed states evenly. In order to meet such a requirement, in the high molecular compound containing metals, a particular substituent (a carboxyl group, a hydroxyl group, an amino group, an ester group or the like) should preferably be coordinated with the metals. However, the occurrence of crosslinking reaction must be prevented.

[0032] Needless to state, during baking, high molecular compound must be

prevented from being fused, desorbed or sublimated. Especially, from the latter viewpoint, specifically, the use of, e.g., polyimide, is particularly preferred.

[0033] However, since a polyimide material is generally insoluble in organic solvent, it is difficult to directly deposit this material on the substrate to form a film. Normally, therefore, corresponding precursor polyamic acid is deposited, and then a polyimide film is obtained by performing chemical or thermal dehydration/cyclization (conversion into imide). For the method of obtaining such a polyimide film having metals or metal oxides dispersed therein to be used for the invention, a method of conversion into imide can be used, which mixes a desired metal or organometallic compound with polyamic acid, and deposits the mixture to form a film thereby obtained on a desired substrate.

[0034] In many cases, however, the foregoing method is unusable. A reason is that if the above metal elements are mixed with the polyamic acid, since the coordinating force of the carboxyl group in the polyamic acid with the metal is strong, crosslinking reaction occurs in molecules or between molecules to cause gelation. To form a film of high molecular compound once gelled is extremely difficult. In order to solve this problem, the inventors presented a method of uniformly forming a film having metals, especially palladium and/or palladium oxides dispersed in polyimide (Patent Application, filed on Aug. 11, Hei 6 (1994), reference No. 2742007, Title of the Invention: Method for forming low-resistant polyimide film containing metals and/or metal oxides, and Liquid crystal device using the same as an alignment film, applied by Canon Inc.). The method described therein can also be used for the present invention.

[0035] The invention should not be limited to the above method. To describe the method, it specifically comprises the steps of: depositing a material on the substrate using polyamic acid ester as a target polyimide precursor, the material being made of a mixture of the polyamic acid ester with metal palladium or an organopalladium compound, preferably a complex compound having weak interaction between the palladium and the ester portion of the polyamic acid ester; and subsequently converting the polyamic acid ester into imide chemically and/or thermally. The structure of the polyamic acid ester is indicated by the following formula (1).

[0036]

[Chemical Formula 1]

(1)

[0037] In the formula (1), R_3 denotes an alkyl group having the number of carbons equal to 1 or higher. Polyamic acid is a result of substituting hydrogen for the alkyl group. Thus, for R_1 and R_2 , not only conventionally known ones having the same structure as that of the polyamic acid but also others may be used.

[0038] The specific examples of R_1 and R_2 are indicated by the following formula 2.

[0039]

[Chemical Formula 2]

Specific example of R_1 in the formula (1)

Specific example of R_2 in the formula (1)

[0040] In addition, a copolymer made of two kinds or more polyamic acid esters may be used. The polyamic acid ester can be easily synthesized by a conventionally known method. For example, the polyamic acid ester is obtained by using corresponding polyamic acid as a starting material, and reacting its acid chloride with alcohol or alkoxide containing a desired alkyl group (R_3 in this case).

[0041] There is no particular limitation placed on the upper limit of the number of carbons of R_3 . However, as desorption is necessary during conversion into imide, the number of carbons should not be too large. Preferably, the number should be set equal to 1 or higher to 30 or lower, more preferably 1 or higher to 22 or lower. The polyamic acid ester is usually soluble in polar solvent such as N, N-dimethyl acetamide (referred to as DMAc, hereinafter), 2-N-methyl pyrrolidine (referred to as NMP, hereinafter), γ -butyl lactone or the like, or mixed solvent containing the same.

[0042] Then, metal palladium or an organopalladium compound is mixed in the solution of the polyamic acid ester dissolved in the solvent, and the solution of the mixture thereof (referred to as polyamic acid ester - Pd mixture, hereinafter) is prepared. In this case, the use of the organopalladium compound rather than the metal palladium is preferred because of its relatively easy solution in organic solvent. For the structure of the organopalladium compound, as described above, one having a weak complex formed with the ester portion of the polyamic acid ester is particularly preferred.

[0043] In other words, the preferable organopalladium compound is one having two ligands or one having four ligands, at least two thereof being easily desorbed. Specific structure examples are indicated by the following general formulas (2) to (4).

[0044]

[Chemical Formula 3]





[0045] In the formulas (2) to (4), each of R_4 , R_5 , R_6 and R_7 denotes a hydrocarbon chain having the number of carbons equal to 1 or high to 30 or lower. As hydrocarbon chains, for example, a methyl group, a decyl group, an octadecyl group, and so on, are available. Among these R_4 to R_7 , R_4 may be hydrogen. For the R_5 to R_7 , one to two of these may be hydrogen. In other words, for alkylamine coordinated with palladium, any amines of 1st to 3rd class may be used. The hydrogen constituting the R_4 to R_7 may be substituted partially or all by fluorine.

[0046] The polyamic acid ester · Pd complex prepared in the foregoing manner is then deposited on a desired substrate by a proper method, and thereby a polyamic acid ester · Pd complex film is obtained. In this case, since the polyamic acid ester · Pd complex is not gelled, so the method of depositing the complex on the substrate, one can be selected from a variety of conventionally known thin film deposition methods including a rotational coating method, a dipping method, Langmuir-Blodgett (abbreviated to LB, hereinafter) method, and so on. Among these methods, the use of the rotational coating method or the dipping method is easiest, but the formation of a film uniform over a wide area on the substrate is not necessarily easy. In addition, the controllability of a film thickness is not so good. On the other hand, the use of the LB method can obtain a uniform film relatively easily with good reproducibility.

[0047] Now, description will be made of the chemical structure of a material to be used when the polyamic acid ester · Pd complex film is deposited on the substrate by using the LB method. It is important that a polyamic acid ester · Pd complex suitably used for the LB method should have a good balance between hydrophilicity and hydrophobicity so as to form a monomolecular film when the complex is developed on a water surface. Accordingly, the complex should preferably have the number of carbons equal to 8 or higher to 30 or lower and, more preferably, it should have an alkyl chain having the number of carbons equal to 10 or higher to 22 or lower, at a rate of 0.5 or higher per monomer unit.

[0048] As the example of such polyamic acid ester · Pd, there is one, where regarding the structure of the polyamic acid portion (general formula (1)), for example, the number of carbons is 8 or higher to 30 or lower, and more

preferably, the number of carbons is 10 or higher to 22 or lower.

[0049] In this case, no particular limitation is placed on the structure of an organopalladium compound mixed with the polyamic acid ester. However, for example, when one of the compounds indicated by the formulas (2) to (4) is used, the number of carbons constituting R₄ to R₇ may not be so large, and one indicated by a formula (5) or (6) can be used.

[0050]

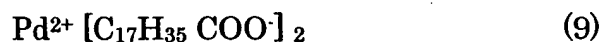
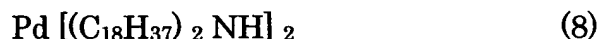
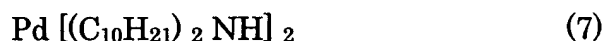
[Chemical Formula 4]



[0051] Conversely, even when the number of carbons is small for R₃ of the polyamic acid ester, e.g., 1, if the organopalladium compound to be mixed therewith has the number of carbons equal to 8 or higher to 30 or lower, preferably one or more alkyl groups of the number of carbons equal to 10 or higher to 22 or lower, the monomolecular film of the polyamic acid ester - Pd complex can be formed. No problems will occur even if the number of carbons is smaller. Thus, the organopalladium compound to be used in this case is one like that indicated by, for example the following formulas (7) to (9).

[0052]

[Chemical Formula 5]



[0053] The use of the foregoing material is not limited to the LB method, but the material can be used for other thin film forming methods, i.e., the rotational coating method and the dipping method. Needless to state, if the method of deposition of a thin film other than the LB method is used, in addition to the foregoing material, a polyamic acid ester - Pd complex having an alkyl group of a smaller number of carbons can be used.

[0054] After the deposition of the polyamic acid ester - Pd complex on the substrate by using any one of the above-described methods, conversion into imide is carried out. As the method of conversion into imide, there are a method of performing chemical conversion by dipping a sample in solution containing pyridine and acetic anhydride (abbreviated to solution

converting into imide, hereinafter), and a method of performing thermal conversion. In the former case, the palladium or the organopalladium compound may be dissolved again in solution converted into imide. Thus, the latter method is preferable.

[0055] Such conversion into imide results in the desorption and imide cyclization of the R_3O - group of the polyamic acid ester, and thus polyimide indicated by the following formula (10) is formed.

[0056]

[Chemical Formula 6]

(10)

[0057] If a heat treatment is employed for conversion into imide, the temperature of the treatment more or less depends on the structure of polyamic acid ester. However, the treatment is carried out at a temperature of 250 to 400 °C. If the heat treatment is carried out for the polyamic acid ester - Pd complex, especially if the polyamic acid ester - Pd complex contains an organopalladium compound, ligands in the organopalladium compound are desorbed, leaving palladium.

[0058] In this case, if the heating temperature is 300 °C or higher and oxygen is present, the palladium is oxidized to form a palladium oxide. In this way, a polyimide film containing the palladium and/or the palladium oxide is formed, which can be used for the invention. The polyimide and the palladium oxide are not coordinated with each other, but the palladium and/or the palladium oxide is evenly dispersed in the polyimide. Before the step of the conversion into imide, for the purpose of eliminating solvents contained in the film, the film may be heated at a low temperature (e.g., 150 °C), or left under a reduced pressure.

[0059] The specific example of the palladium dispersed in the polyimide has been described. No limitation should be placed in this regard, and other metal elements and high molecular compounds, e.g., polymethacrylate acid, polyester, and so on, may be used.

[0060] In any case, after the deposition of the high molecular compound

containing metals on the substrate 1, to convert the high molecular compound into amorphous carbons or graphite, baking is subsequently carried out. In the baking step, it is only necessary to convert the high molecular compound at least partially, preferably fully, into carbons, and a baking temperature is set in the range of 600 to 3000 °C. As can be easily expected, within the above range of the baking temperature, amorphous carbons are obtained at a low temperature and, as the temperature is increased, conversion into graphite is facilitated. Specifically, the conversion into graphite (crystallization) starts at a high temperature of 1800 °C or higher.

[0061] In this case, graphite having a smaller number of defects can be obtained with a higher temperature. However, if baking is carried out at a temperature of 2600 °C, conversion into graphite has already been substantially completed, and thus the baking at this temperature or higher is useless. In the invention, graphite is not always necessary. Apparently, therefore, for device manufacturing, a treatment should preferably be carried out at a temperature as low as possible, which enables restrictions placed regarding the heat resistances of the members to be used (substrate 1, and so on) to be softened.

[0062] Depending on the type of metal to be used, evaporation may occur if a treatment is carried out at too high a temperature. Thus, needless to state, the treatment should be executed at a temperature equal to the evaporation temperature or lower. It can therefore be understood that a proper baking temperature is 1500 °C or lower, more preferably, 1000 °C or lower. If the temperature is too low, however, since any amorphous carbons cannot be obtained, the baking at least at a temperature of 600 °C is necessary.

[0063] The baking step should preferably be performed under the condition of dilute oxygen, such as in vacuum or nitrogen atmosphere. Regarding the case of using the polyimide as the high molecular compound, it has conventionally known that amorphous carbons or graphite can be formed by baking the polyimide (e.g., a thesis by B. Nysten and et al., (p. 12527 to 12538, Physical Review B, Vol. 48, 1993).

[0064] In the foregoing fashion, the thin film 2 for forming an electron emitting portion is formed on the substrate 1, which is made of amorphous

carbons, graphite or a mixture thereof, containing metals or metal oxides. The film thickness of the thin film 2 for forming the electron emitting portion should preferably be set in the range of several Å to several thousand Å, especially in the range of 10 to 500 Å. The film thickness is properly set under the conditions of the electron emitting portion 3, a resistance value between the device electrodes 5 and 6, described later, the particle sizes of the conductive fine particles of the electron emitting portion 3, and an energizing processing condition, and so on. The sheet resistance value thereof is set in the range of 10^3 to $10^7 \Omega/\text{cm}^2$.

[0065] For the thin film 2 for forming the electron emitting portion, patterning needs to be carried out as occasion demands. For this purpose, the conventionally known photolithography technology is used and, specifically, an etching method or a lifting-off method can be used. In the case of using the lifting-off method having a photoresist set as a peeling layer, since the heat resistance of the photoresist is normally equal to a heating temperature or lower necessary in the baking step of the invention, patterning must be carried out before the baking step, i.e., at a point of time when the film made of a high molecular material containing metals is deposited on the substrate 1. In the case of using the etching method, patterning may be carried out before or after the baking step. Especially, if the polyimide is used as a high molecular material, patterning may be executed in the state of its precursor.

[0066] Subsequently, a pair of device electrodes 5, 6 (see Fig. 2b) are formed on the substrate 1 in such a way as to be partially or fully deposited on the surface of the thin film 2 for forming the electron emitting portion. As materials for the device electrodes 5 and 6, any conductive materials can be used, and examples include a metal such as Ni, Cr, Au, Mo, W, Pt, Ti, Al, Cu, Pd or the like, or an alloy thereof, metal such as Pd, Ag, Au, RuO₂, Pd-Ag or the like, and a printing conductor made of glass and a metal oxide or the like, a transparent conductive material such as In₂O₃ - SnO₂ or the like, a semiconductor conductive material such as silicon, and so on.

[0067] For the method of deposition, any conventionally known methods can be used, e.g., a vacuum evaporation method, a sputtering method, and so on. The above material is deposited in a desired shape, or after the deposition, patterning is carried out by the photolithography technology

such as the lifting-off method, the etching method or the like so as to obtain a desired shape. In this way, the device electrodes 5 and 6 are formed.

[0068] An interval L_1 between the device electrodes is set in the range of several hundred Å to several hundred μm . The interval is set by the photolithography technology as a basis for the manufacturing method of the device electrodes, specifically depending on the performance of an exposure device, the etching method, a voltage applied between the device electrodes, a field strength for enabling electron emission, and so on. The preferred interval is in the range of several μm to several tens of μm . An electrode length W_1 , a film thickness d of the device electrodes 5 and 6, the resistance value of each electrode, connections with the above-described X-direction and Y-direction wirings, and the arranging problems of a number of electron sources disposed are properly designed. Usually, the electrode length W_1 is set in the range of several μm to several hundred μm , and the film thickness d of the device electrodes 5 and 6 is set in the range of several hundred Å to several μm .

[0069] For manufacturing the device, the device electrodes 5 and 6 may be first formed on the substrate, and then the thin film 2 for forming the electron portion may be formed. In this case, however, since baking is performed after the formation of the device electrodes, heat resistance is required of the device electrodes 5 and 6.

[0070] Subsequently, energizing processing called forming is executed. Specifically, when a pulse-like voltage or a boosted voltage is applied between the device electrodes 5 and 6 by a not-shown power source, the thin film 2 for forming the electron emitting portion is locally fractured, deformed or altered. Such a structurally changed portion is called an electron emitting portion 3 (see Fig. 2c). Also, the thin film 2 for forming the electron emitting portion after the electron emitting portion 3 is formed is referred to as a thin film 4 including an electron emitting portion.

[0071] The electron emitting portion 3 contains a number of conductive fine particles having particle diameter sizes preferably set in the range of several Å to several hundred Å, more preferably in the range of 10 to 500 Å. The particle diameter sizes are properly set depending on the manufacturing method including the film thickness of the thin film 4 having the electron emitting portion, an energizing processing condition,

and so on. A material constituting the electron emitting portion 3 has elements partially or fully similar to those of a material constituting the thin film 4 having the electron emitting portion.

[0072] In Figs. 1 and 2, the electron emitting portion is formed partially between the opposing device electrodes 5 and 6. Depending on the manufacturing method, however, all the parts between the opposing device electrodes 5 and 6 may function as electron emitting portions.

[0073] The forming and an electrical treatment thereafter are carried out inside a measuring and evaluating device shown in Fig. 3. The measuring and evaluating device is described hereinbelow. Fig. 3 is a constitutional view schematically showing the measuring and evaluating device for measuring the electron emission characteristic of a device having a configuration like that shown in Fig. 1. In Fig. 3, a reference numeral 1 denotes a substrate; 5 and 6 device electrodes; 4 a thin film including an electron emitting portion; and 3 an electron emitting portion. A reference numeral 31 denotes a power source for applying a device voltage V_f to the device; 30 an ammeter for measuring a device current I_f flowing to the thin film 4 having the electron emitting portion between the device electrodes 5 and 6; 34 an anode electrode for capturing an electron emission current I_e from the electron emitting portion 3; 33 a high voltage power source for applying a voltage to the anode electrode; and 32 an ammeter for measuring the electron emission current I_e .

[0074] For measuring the device current I_f and the electron emission current I_e of the electron emitting device, the power source 31 and the ammeter 30 are connected to the device electrodes 5 and 6, and the anode electrode 34, to which the power source 33 and the ammeter 32 are connected, is disposed in the upper side of the electron emitting device. In addition, the electron emitting device and the anode electrode 34 are installed inside a vacuum device. The vacuum device is provided with necessary equipments including an exhaust pump, a vacuum gauge, and so on, not shown. Under desired vacuum, the electron emitting device is measured and evaluated.

[0075] The exhaust pump is composed of a normal high vacuum device system having a turbine pump and a rotary pump, and an ultra-high vacuum device system having an ion pump. The entire vacuum device and

the electron emitting device can be heated up to a temperature of 200 °C by a not-shown heater. The measurement was executed with the voltage of the anode electrode 34 set in the range of 1 to 10 kV, and a distance H between the anode electrode and the electron emitting device set in the range of 2 to 8mm.

[0076] The FORMING operation was executed in the vacuum atmosphere of about 10^{-5} torr. There are cases of applying a voltage pulse having a constant peak value, and of applying a voltage pulse while increasing a peak value. First, the case of applying a voltage pulse having a constant peak value is described with reference to Fig. 4(a) showing its voltage waveform.

[0077] In Fig. 4(a), T_1 and T_2 respectively denote a pulse width and a pulse interval of the voltage waveform. T_1 was set in the range of 1 μ sec. to 10 msec., T_2 was set in the range of 10 μ sec. to 100 msec., and the peak value of a triangular wave (peak voltage during FORMING) was properly selected. Fig. 4(b) shows a voltage waveform in the case of applying a voltage pulse while increasing a peak value.

[0078] In Fig. 4(b), T_1 and T_2 respectively denote a pulse width and a pulse interval of the voltage waveform. T_1 was set in the range of 1 μ sec. to 10 msec., T_2 was set in the range of 10 μ sec. to 100 msec., and the peak value of a triangular wave (peak voltage during FORMING) was increased by, for example 0.1 V.

[0079] Regarding the completion of the FORMING operation, a device current was measured to calculate a resistance value by a voltage, e.g., about 0.1 V, causing no local fracture or deformation of the thin film 2 for forming the electron emitting portion in the pulse interval T_2 , and the FORMING operation was finished, for example when the resistance of 1 M Ω or higher was reached. A voltage at this time is referred to as a FORMING voltage V_F .

[0080] In the foregoing FORMING operation, a triangular wave pulse was used. However, a pulse waveform is not limited to the triangular wave, and a waveform such as a rectangular wave may be used. In such a case, a peak value, a pulse width, a pulse interval, and so on, are not limited to the above-described values, and values may be properly selected according to the resistance value or the like of the electron emitting device in such a way

as to form an electron emitting portion well.

[0081] The electron emitting device constructed in the foregoing manner is then driven in vacuum atmosphere having a higher degree of vacuum. The vacuum atmosphere having a higher degree of vacuum means one having a vacuum degree of about 10^{-6} or higher, and an ultra-high vacuum system is more preferable.

[0082] The basic characteristics of the SCE of the invention manufactured based on the foregoing device configuration and manufacturing method will now be described by referring to Fig. 5. Fig. 5 shows a typical example of a relation among the electron emission current I_e , the device current I_f and the device voltage V_f measured by the measuring and evaluating device shown in Fig. 3. In Fig. 5, the electron emission current I_e is shown by an arbitrary unit as it is considerably smaller compared with the device current I_f .

[0083] As can be understood from Fig. 5, the electron emitting device of the invention has three characteristics regarding the electron emission current I_e . First, in the device, when a given voltage, i.e., a device voltage of V_{th} or higher, called a threshold voltage, in Fig. 5, is applied, the electron emission current I_e is suddenly increased. However, if an applied voltage is equal to the threshold voltage V_{th} or lower, almost no electron emission currents I_e are detected. In other words, the electron emitting device is a nonlinear device having a clear threshold voltage V_{th} with respect to the electron emission current I_e .

[0084] Secondly, the electron emission current I_e can be controlled by the device voltage V_f as it depends on the device voltage V_f .

[0085] Thirdly, emission charges captured by the anode electrode 34 depend on the time of applying the device voltage V_f . In other words, the amount of charges captured by the anode electrode 34 can be controlled by the time of applying the device voltage V_f .

[0086] On the other hand, with respect to the device voltage V_f , the device current I_e may show the characteristic of a monotonous increase (referred to as an MI characteristic, indicated by a solid line in Fig. 5), and the characteristic of a voltage control negative resistance (referred to as a VCNR characteristic, indicated by a broken line in Fig. 5). Such characteristics of the device current are dependent on the device

manufacturing method.

[0087] The basic configuration and manufacturing method of the SCE have been described. However, the device of the invention is not limited to the above-described configuration, and so on, and any devices can be applied to an electron source and an image forming apparatus, described later, as long as they have the foregoing three characteristics regarding the electron emission current I_e .

[0088] Next, description will be made of the electron source and the image forming apparatus of the invention. According to the features of the foregoing three characteristics of the SCE of the invention, electrons emitted from the SCE are controlled based on the peak value and the width of a pulse-like voltage applied between the opposing device electrodes at the threshold value V_{th} or higher. On the other hand, almost no electrons are emitted at the threshold value V_{th} or lower. Accordingly, if a number of SCE are arranged and the pulse-like voltage is applied to each device, the amount of electrons emitted from a particular SCE can be controlled. In other words, the electron source and the image forming apparatus can be configured by arraying a plurality of the SCE of the invention on the substrate.

[0089] For the methods of arraying and driving the SCE on the substrate, for example as described above with reference to the conventional case, the arraying method can be employed, which has a number of SCE disposed side by side and a plurality of SCE groups having both ends of each device connected to the wirings, and controls and drives the amount of electrons emitted from the control electrode (referred to as a grid) installed in the upper space of the SCE. Alternatively, the arraying method can be employed, which has a plurality of X-direction wirings electrically insulated from each other basically and a plurality of Y-direction wirings installed in directions crossing the X-direction wirings, the X-direction and Y-direction wirings being set by interpolating an interlayer insulating layer, and has an SCE disposed for each intersection between the X-direction and Y-direction wirings, one of the pair of device electrodes of the device being connected to the X-direction wiring, and the other being connected to the Y-direction wiring. The latter arraying method is called a simple matrix arrangement.

[0090] Next, description will be made of the configuration of the electron

source constructed based on the simple matrix arrangement by referring to Fig. 6. In Fig. 6, a reference numeral 61 denotes an SCE including an electron emitting portion; and 62 and 63 wirings connected to the pair of the device electrodes of the SCE 61. These wirings can be classified as X-direction and Y-direction wirings 62 and 63 based on a difference between installing directions. Regarding a geometrical arrangement, the X-direction and Y-direction wirings 62 and 63 need not be always in an orthogonal relation like that shown in Fig. 6. Usually, however, the wirings are in an orthogonal relation. The X-direction and Y-direction wirings 62 and 63 may also function as the device electrodes of each SCE (united formation).

[0091] Next, description will be made of an example of the manufacturing method of an electron source substrate structured based on a simple matrix arrangement like that shown in Fig. 6. On the insulating substrate 1, a thin film for forming an electron emitting portion is deposited in a desired pattern, which is made of the conductive fine particles and graphite, or amorphous carbons of the invention or a mixture thereof. The method of deposition is the same as that described above with reference to the manufacturing method of the SCE.

[0092] Then, the number m of X-direction wirings 62, i.e., $Dx1, Dx2, \dots, Dxm$, are formed on the substrate 1 having the thin film for forming the electron emitting portion by a vacuum evaporation method, a printing method, a sputtering method or the like. Further, after a not-shown interlayer insulating layer is formed, the number n of Y-direction wirings 63, i.e., $Dy1, Dy2, \dots, Dyn$, are formed by the same method for the X-direction wirings. The codes m and n are both integral numbers. A patterning type and the patterns of the X-direction and Y-direction wirings are designed such that the patterned thin film for forming the electron emitting portion can be electrically brought into contact with or connected to the X-direction and Y-direction wirings. In addition, materials, film thickness and wiring widths are set for the X-direction and Y-direction wirings such that a roughly uniform voltage can be applied to each patterned thin film for forming the electron emitting portion.

[0093] The interlayer insulating layer, not shown, is a SiO_2 film or the like formed by a vacuum evaporation method, a printing method, a sputtering

method or the like. This film is formed in a desired shaped on the full surface or a part of the substrate 1 including the X-direction wirings and the patterned thin film for forming the electron emitting portion. A film thickness, a material and a manufacturing method thereof are properly set in order to endure a potential difference at the intersection between the X-direction and Y-direction wirings 62 and 63 especially during driving. Then, a forming operation is executed for each thin film for forming the electron emitting portion, resulting in the formation of the SCE 61. This process will be described in detail later.

[0094] The X-direction and Y-direction wirings 62 and 63 are respectively drawn out as external terminals. As described in detail later, the X-direction wirings 62 are electrically connected to not-shown scanning signal applying means provided to apply a scanning signal to each row of the SCE 61 arrayed in the X direction. On the other hand, the Y-direction wirings 63 are electrically connected to not-shown modulating signal generating means provided to apply a modulating signal to each column of the SCE 61 arrayed in the Y direction. A driving voltage applied to each device of the SCE 61 is supplied as a difference voltage between a scanning signal and a modulating signal applied to the device.

[0095] Next, description will be made of the image forming apparatus using the electron source constructed in the foregoing manner by referring to Figs. 7 and 8. Fig. 7 shows the basic configuration of the image forming apparatus, and Fig. 8 shows a fluorescent screen.

[0096] In Fig. 7, a reference numeral 9 denotes an electron source substrate constructed based on a matrix arrangement, which includes the substrate 1, the SCE 61 and the X-direction and Y-direction wirings 62 and 63; 71 a rear plate having the electron source substrate 9 fixed thereto; 76 a face plate having a fluorescent screen 74, a metal back 75, and so on, formed on a surface opposite the electron source substrate 9 of the glass substrate 73; and 72 a supporting frame. Flit glasses are coated on the rear plate 71, the supporting frame 72 and the face plate 76. Then, these are baked in atmosphere or nitrogen atmosphere at a temperature of 400 to 500 °C for 10 min. to be sealed, thereby constituting an envelope 78.

[0097] In this case, since the rear plate 71 included in the envelope 78 is provided mainly for the purpose of reinforcing the strength of the electron

source substrate 9, the separate rear plate 71 is unnecessary if the electron source substrate 9 itself has a sufficient strength. The supporting frame 72 may be directly sealed to the electron source substrate 9, and the envelope 78 may be constituted of the face plate 76, the supporting frame 72 and the electron source substrate 9. With respect to the X-direction and Y-direction wirings 62 and 63, these elements are connected to out-of container terminals Dox1 to Doxm and Doy1 to Doyn.

[0098] Fig. 8 shows the fluorescent screen 74 in detail. The fluorescent screen 74 is made of only a fluorescent substance in the case of a monochromatic displaying. In the case of color displaying, however, the fluorescent screen 74 is made of a black conductive material 81 called a black stripe (Fig. 8(a)) or a black matrix (Fig. 8(b)), and a fluorescent substance 82. The black stripe or the black matrix is provided for the purpose of preventing a mixed color from becoming conspicuous by coloring black a separately coated portion between the fluorescent substances 82 of three primary color fluorescent substances necessary for color displaying, and limiting a reduction in contrast caused by external light reflection on the fluorescent screen 74.

[0099] The material of the black stripe or the black matrix is not limited to a generally used material containing graphite as a main component, and any conductive materials having little light transmission and reflection can be used. For the method of coating the fluorescent substance 82 on the glass substrate 73, a method of deposition or a printing method can be used irrespective of monochromatic displaying or color displaying.

[0100] The metal back 75 is generally provided in the inner surface side (surface facing the electron source substrate 9) of the fluorescent screen 74. The metal back is provided for the purposes of improving luminance by mirror-reflecting, among lights emitted from the fluorescent substance, a light emitted to the inner surface side on the face plate 76 side, using the metal back as an electrode for applying an acceleration voltage to emitted electrons, reducing the damaging of the fluorescent substance 82 caused by the collision of negative ions generated in the envelope 78, and so on. The metal back 75 can be manufactured by smoothing (generally called filming) the inner side surface of the fluorescent screen 74 after the formation of the fluorescent screen 74, and then depositing aluminum by vacuum

evaporation or the like. In the face plate 76, to further enhance the conductivity of the fluorescent screen 74, a transparent electrode (not shown) may be provided in the outer surface side thereof.

[0101] To execute the foregoing sealing, in the case of color displaying, since a corresponding relation needs to be set between each fluorescent substance and each SCE, sufficient alignment must be carried out for both.

[0102] Subsequently, through a not-shown exhaust pipe, for example by using a general vacuum system composed of a rotary pump and a turbine pump, the envelope 78 is set at the vacuum degree of 10^{-6} torr inside, a voltage is supplied through the out-of container terminals Dox1 to Doxm and Doy1 to Doyn to the patterned thin film for forming the electron emitting portion, and then forming is carried out to form the SCE 61.

[0103] Subsequently, while executing baking at a temperature of 80 to 150 °C for 3 to 15 hours, the vacuum system is switched to an ultra-high vacuum system, which is a pump system, e.g., an ion pump. The switching to the ultra-high vacuum system and the baking are carried out to satisfy the above-described monotonous increase characteristic (MI characteristic) of the device current I_f and electron emission current I_e of the SCE, and a method and conditions are not limited to these.

[0104] The envelope 78 is sealed after the above operation. To maintain the degree of vacuum after the sealing, however, a getter treatment may be performed. The getter treatment is executed to form a deposited film by using a heating method such as resistance heating, a high-frequency heating or the like to heat a getter disposed in a specified position (not shown) in the envelope 78, the getter heating being carried out immediately before or after the sealing of the envelope 78. A typical main component for the getter is Ba or the like, which is used to maintain the degree of vacuum at, for example 1×10^{-5} to 1×10^{-7} torr by means of the adsorbing operation of the deposited film.

[0105] In the image forming apparatus of the invention completed in the foregoing manner, electrons are emitted by applying a voltage through the out-of container terminals Dox1 to Doxm and Doy1 to Doyn to each SCE 61, emitted electrons (electron beams) are accelerated by applying, through a high voltage terminal Hv, a high voltage of several kV or higher to the transparent electrode (not shown) formed on the metal back 75 or the

fluorescent screen 74, the electrons are collided with the fluorescent screen 74, and an image can be displayed by exciting or causing the fluorescent substance 82 to emit a light.

[0106] The foregoing configuration is a schematic one necessary for manufacturing the image forming apparatus used for displaying or the like. For example, the materials of respective members and other specific portions are not limited to the foregoing, and materials are properly selected depending on the use of the image apparatus.

[0107]

[Embodiments] Next, the present invention will be described more in detail with reference to the preferred embodiments.

[0108] Embodiment 1

The basic configuration of the SCE of the described embodiment is roughly similar to the plan and sectional views of Figs. 1(a) and 1(b), and its manufacturing method is basically similar to that shown in Fig. 2

[0109] Now, the SCE manufacturing method will be describe step by step with reference to Fig. 2.

Step - a

The DMAc solution (monomer reduced concentration: 2 mmol/l) of polyamic acid methyl ester indicated by a formula (11) and the chloroform solution (concentration: 40 mmol/l) of palladium acetate indicated by the formula (5) were mixed at 20: 1 (v/v) (mixture prepared in this manner is referred to as a mixture I).

[0110]

[Chemical Formula 7]

(11)

[0111] The mixture I was deposited on the cleaned quartz substrate 1 by a rotational coating method. The conditions for the rotational coating were 1000 rpm, and 30 sec.

[0112] Then, the sample was heated by using an infrared ray heating furnace under the flow of nitrogen at a temperature of 150 °C for 30 min.

The sample was subsequently heated at a temperature of 300 °C for 30 min., and a film made of polyimide (formula (10)) and palladium oxide was formed. Further, the film was baked at a temperature of 700 °C for 20 min., and a thin film 2 for forming an electron emitting portion was formed, which was made of amorphous carbons and a palladium oxide. The film thickness thereof was 100 Å, and the sheet resistance value was $2 \times 10^4 \Omega/\text{cm}^2$.

[0113] The thin film 2 for forming the electron emitting portion was then subjected to dry etching using CF_4 gas to obtain a desired pattern. On the substrate 1 having the thin film 2 for forming the electron emitting portion, a pair of opposing device electrodes 5 and 6 were formed by using a lifting-off method in such a way as to set an interval L_1 between the device electrodes equal to 3 μm and the width W_1 of the device electrode equal to 300 μm . Specifically, after the desired pattern was formed by a photoresist (RD – 2000 N – 41, by Hitachi Kasei, inc.), a Ti film having a thickness of 50 Å and an Ni film having a thickness of 1000 Å were sequentially deposited with vacuum deposition method. Then, the photoresist pattern was dissolved in organic solvent, the Ni/Ti deposited films were partially lifted off, and thus the device electrodes 5 and 6 made of Ni/Ti, having desired shapes, were obtained.

[0114] Step – b

Then, the foregoing device was set on the measuring and evaluating device shown in Fig. 3, and evacuated by the vacuum pump. After the vacuum degree of 2×10^{-5} torr was reached, voltages were applied to the device electrodes 5 and 6 by using the power source 31 for applying a device voltage to the device, and an energizing (FORMING) processing was carried out. The voltage waveform of the FORMING operation is shown in Fig. 4b.

[0115] In Fig. 4b, T_1 and T_2 respectively denote the pulse width and the pulse interval of the voltage waveform. In the described embodiment, T_1 was set equal to 1 msec., T_2 was set equal to 10 msec., the peak value (peak value during forming) of a rectangular wave was increased by 0.1 V, and the FORMING operation was executed.

[0116] In this case, simultaneously, a resistance measuring pulse was inserted into T_2 at a voltage of 0.1 V to measure resistance. When a measured value by the resistance measuring value reached about 1 M Ω or

higher, the FORMING operation was finished. A FORMING voltage V_F for each device was 5.1 V.

[0117] In this way, an electron emitting portion 3 was formed. When the formed electron emitting portion 3 was observed by a scanning electron microscope (SEM) or an electron microscope (TEM), fine particles containing a palladium element as a main component were observed to be dispersed in amorphous carbons, and an average particle diameter size among the fine particles was 30 Å.

[0118] The electron emission characteristic of the SCE constructed in the foregoing manner was measured by using the measuring and evaluating device shown in Fig. 3. A distance between the anode electrode and the electron emitting device was 4 mm, the potential of the anode electrode was 1 kV, and the degree of vacuum in the vacuum device was 1×10^{-6} torr during the measurement of the electron emission characteristic. Fig. 9 shows a relation among the device voltage V_f , the device current I_f and the electron emission current I_e when a triangular wave was voltage-applied to the device at a sweeping speed of about 0.005 Hz.

[0119] The device current I_f was monotonously increased with the increase of the device voltage V_f , and then showed a voltage control negative resistance at $V_f = 5$ V or higher. At $V_f = 10$ V or higher, the device current I_f was about 1 mA, which was 1/several values of the maximum value of the device current. When the device voltage was applied between the two device electrodes 5 and 6, the device current I_f and the electron emission current I_e stable from the beginning were observed. Specifically, the device current I_f was 2.0 mA, the electron emission current I_e was 1.0 μ A, and electron emission efficiency $\eta = I_e/I_f$ was 0.05 %.

[0120] Embodiment 2

Similarly to the embodiment 1 except for the fact that the material of the thin film 2 for forming the electron emitting portion and the manufacturing method of the embodiment 1 were changed as described below, an SCE was manufactured. The DMAc solution (monomer reduced concentration: 2 mmol) of polyamic acid octadecyl ester indicated by a formula (12) and the chloroform solution (concentration: 40 mmol) of the palladium acetate indicated by the formula (5) were mixed at 20 : 1(v/v) (mixture prepared in this manner is referred to as a mixture II ,

hereinafter).

[0121]

[Chemical Formula 8]

(12)

[0122] The mixture II was deposited on the quartz substrate 1 by an LB method. Now, the LB method is described in detail.

[0123] A surface pressure was increased to 20 mN/m after the DMAc – chloroform (20 : 1) mixed solution of the mixture II was developed on the pure water of a temperature 20 °C, and the monomolecular film of the mixture II was formed on the pure water. While the surface pressure was maintained, the quartz substrate 1 exposed to hexamethyl di-silazane atmosphere beforehand to make its surface hydrophobic was slowly dipped in a direction crossing the monomolecular film at a speed of 6 mm/min., the substrate was subsequently taken up at the same speed, and a 2-layer LB film of the mixture II was laminated on the quartz substrate 1. By repeating the dipping and taking-up operations, an 50-layer LB film made of the mixture II was formed.

[0124] Then, the sample was heated by using an electric furnace under a reduced pressure, and at a temperature of 300 °C for 30 min. Then, the pressure was returned to a normal pressure (air substitution), and the sample was heated at a temperature of 350 °C for 15 min. Subsequently, the sample was baked in nitrogen atmosphere at a temperature of 700 °C for 20 min., and thereby a thin film 2 for forming an electron emitting portion, which was made of amorphous carbons and a palladium oxide, was obtained. The film thickness thereof was 100 Å, and the sheet resistance value was $2 \times 10^4 \Omega/\text{cm}^2$.

[0125] The thin film 2 for forming the electron emitting portion was subjected to dry etching using CF_4 gas to obtain a desired pattern. On the substrate 1 having the thin film 2 for forming the electron emitting portion, device electrodes 5 and 6 similar to those of the embodiment 1 were formed by using the same method.

[0126] Then, a FORMING operation was carried out by completely the same method as that for the embodiment 1, and thereby an SCE was made. When the electron emitting portion 3 of the SCE was observed by the SEM or TEM, fine particles containing a palladium element as a main component were observed to be dispersed in amorphous carbons, and an average particle diameter size among the fine particles was 30 Å.

[0127] The electron emission characteristic of the SCE was measured with the same method as the embodiment 1, and a device current I_f and an electron emission current I_e were observed to be stable from the beginning. Specifically, when a device voltage was 14 V, the device current I_f was 2.0 mA, the electron emission current I_e was 1.4 μ A, and electron emission efficiency $\eta = I_e/I_f$ was 0.07 %.

[0128] Embodiment 3

Similarly to the embodiment 1 except for the fact that the material and the manufacturing method of the thin film 2 for forming the electron emitting portion were changed as described below, an SCE was manufactured. The DMAc solution (monomer reduced concentration: 2 mmol) of the polyamic acid methyl ester indicated by the formula (11) and the chloroform solution (concentration: 40 mmol) of the bis-(dodecyl amine) palladium complex indicated by the formula (7) were mixed at 20: 1 (v/v) (mixture prepared in this manner is referred to as a mixture III). The mixture III was deposited on the quartz substrate 1 by using the LB method.

[0129] Now, the LB method is described in detail. After the DMAc - chloroform (20 : 1) mixed solution of the mixture III was developed on the pure water of a temperature 20 °C, a surface pressure was increased to 20 mN/m, and the monomolecular film of the mixture III was formed on the pure water. While the surface pressure was maintained, the quartz substrate 1, the surface thereof having been treated by hexamethyl di-silazane beforehand to be hydrophobic, was slowly dipped in a direction crossing the monomolecular film at a speed of 10 mm/min. Then, the substrate was taken up at the same speed, and the 2-layer LB film of the mixture III was laminated on the quartz substrate 1. By repeating the dipping and taking-up operations, a 70-layer LB film made of the mixture III was formed.

[0130] Subsequently, the sample was heated by using the electric furnace

under a reduced pressure, and at a temperature of 300 °C for 30 min. Then, the pressure was returned to a normal pressure (air substitution), and the sample was heated at a temperature of 350 °C for 15 min. Subsequently, the sample was baked in nitrogen atmosphere at a temperature of 700 °C for 20 min., and a thin film 2 for forming an electron emitting portion was formed, which was made of amorphous carbons and a palladium oxide. The film thickness thereof was 100 Å, and the sheet resistance was $2 \times 10^4 \Omega/\text{cm}^2$.

[0131] The thin film 2 for forming the electron emitting portion was subjected to dry etching using CF_4 gas to obtained a desired pattern. On the substrate 1 having the thin film 2 for forming the electron emitting portion, device electrodes 5 and 6 similar to those of the embodiment 1 were formed by using the same method.

[0132] Then, a FORMING operation was carried out by completely the same method as that of the embodiment 1, and thereby an SCE was made. When the electron emitting portion of the SCE was observed by the SEM or TEM, fine particles containing a palladium element as a main component were observed to be dispersed in amorphous carbons, and an average particle diameter size among the fine particles was 30 Å.

[0133] The electron emission characteristic of the SCE was measured as in the case of the embodiment 1. A device current I_f and an electron emission current I_e were observed to be stable from the beginning. Specifically, when a device voltage was 14 V, the device current I_f was 2.0 mA, the electron emission current I_e was 1.4 μA , and electron emission efficiency $\eta = I_e/I_f$ was 0.07 %.

[0134] Embodiment 4

The substrate was made of sapphire in place of quartz, and other portions were similar to those of the embodiment 2. The mixture II was deposited to form a film on the sapphire substrate by using the LB method (50 layers).

[0135] Then, the sample was heated by using the electric furnace under a reduced pressure, and at a temperature of 300 °C for 30 min. Then, the pressure was returned to a normal pressure (air substitution), and the sample was heated at a temperature of 350 °C for 15 min.

[0136] Subsequently, the sample was baked in argon atmosphere at a

temperature of 1800 °C for 20 min., and thereby a thin film 2 for forming an electron emitting portion was obtained, which was made of carbons partially converted into graphite and a palladium oxide.

[0137] The film thickness of the film 2 was 100 Å, and the sheet resistance value thereof was $1 \times 10^4 \Omega/\text{cm}^2$. The partial formation of graphite was verified by using the TEM and an STM.

[0138] Then, an SCE was manufactured by the method described above with reference to the embodiment 2.

[0139] The electron emission characteristic of the SCE was measured as in the case of the embodiment 1, and a device current I_f and an electron emission current I_e were observed to be stable from the beginning.

[0140] Specifically, when the device voltage was 14 V, the device current I_f was 2.2 mA, the electron emission current I_e was 1.8 μA , and electron emission efficiency $\eta = I_e/I_f$ was 0.08 %.

[0141] Embodiment 5

Other than the change of the sapphire substrate of the embodiment 4 to a magnesium oxide substrate and the change of the step of heating executed in the argon atmosphere at the temperature of 1800 °C for 20 min, among the heating steps, to heating at a temperature of 2200 °C for 20 min, an SCE was manufactured by completely the same method as that of the embodiment 4.

[0142] Verification was made by using the TEM and the STM as to the fact that a thin film 2 for forming an electron emitting portion was made of graphite and a palladium oxide.

[0143] The electron emission characteristic of the SCE was measured, and it was discovered that when the device voltage was 14 V, a device current I_f was 2.4 mA, an electron emission current I_e was 1.9 μA , and electron emission efficiency $\eta = I_e/I_f$ was 0.08 %.

[0144] Embodiment 6

The embodiment 6 is an example of an image forming apparatus comprising a number of SCE arranged in a simple matrix pattern. Fig. 10 is a plan view partially showing an electron source. Fig. 11 is a sectional view taken on line A-A' of Fig. 10. In Figs. 10 and 11, like reference numerals denotes like portions. A reference numeral 1 denotes a substrate; 62 an X-direction wiring (also referred to as lower wiring) corresponding to

Dxm of Fig. 7; 63 a Y-direction wiring (also referred to as upper wiring) corresponding to Dyn of Fig. 7; 3 an electron emitting portion; 4 a thin film including an electron emitting portion; 5 and 6 device electrodes; 123 an interlayer insulating layer; and 124 an opening portion for electrically connecting the device electrode 6 to the upper wiring and causing electron emission.

[0145] Next, specific description will be made of the manufacturing method in the sequence of steps by referring to Figs. 12 and 13.

Step – a

In order to pattern the thin film 2 for forming the electron emission in a desired shape on the cleaned quartz substrate 1, the Cr film 121 of a thickness 1000 Å having an opening portion was deposited by means of vacuum evaporation through a mask (see Fig. 12(a)).

[0146] Step – b

On the Cr film 121, a 50-layer LB film made of the mixture II was deposited by using the same material and method (LB method) as those of the embodiment 2. Then, the film was heated by using the electric furnace under a reduced pressure, and at a temperature of 300 °C for 30 min. Subsequently, the pressure was returned to a normal pressure (air substitution), and the film was heated at a temperature of 350 °C for 15 min., and thereby a film 122 made of a palladium oxide and polyimide was formed (see Fig. 12(b)).

[0147] Step – c

The Cr film 121 and the film 122 made of the palladium oxide and the polyimide were subjected to etching using acid etchant to be formed in desired patterns. Subsequently, these films were baked in nitrogen atmosphere at a temperature of 1000 °C for 20 min., and then a film 2 for forming an electron emitting portion was obtained, which was made of amorphous carbons and a palladium oxide (see Fig. 12(c)).

[0148] Step –d

Patterns for the device electrodes 5 and 6 and an interval (L_1) between the device electrodes were formed by photoresists (RD-2000 N-41, made by Hitachi Kasei, Inc.). By vacuum evaporation, Ti having a thickness of 50 Å and Ni having a thickness of 1000 Å were sequentially deposited. The photoresist pattern was dissolved in organic solvent, the Ni/Ti deposited

film was lifted off, and the device electrodes 5 and 6 were formed with an interval $L1$ between the device electrodes $L1 = 3 \mu\text{m}$, and the width of the device electrode $W1 = 300 \mu\text{m}$ (see Fig. 12(d))

[0149] Step – e

After the formation of the photoresist pattern of the lower wiring 62, Ti having a thickness of 50 \AA and Au having a thickness of 5000 \AA were sequentially deposited by vacuum evaporation, unnecessary portions were removed by lifting-off, and the lower wiring 62 having a desired shape was formed (see Fig. 12(e)).

[0150] Step – f

Then, an interlayer insulating layer 123 made of a silicon oxide film having a thickness $1.0 \mu\text{m}$ was deposited by an RF sputtering method (see Fig. 13(f)).

[0151] Step – g

In the silicon oxide film deposited in the step f, an opening portion 124 was formed for causing electron emission and electrically connecting the later-described upper wiring 63 to the thin film 2 for forming the electron emitting portion. Specifically, a photoresist pattern was made for forming the opening portion 124, and the interlayer insulating layer 123 was subjected to etching by using the photoresist pattern as a mask to form the opening portion 124. The etching was executed by a reactive ion etching (RIE) method using CF_4 and H_2 gas (see Fig. 13(g)).

[0152] Step – h

After the formation of the photoresist pattern for the upper wiring 63 on the device electrodes 5 and 6, Ti having a thickness of 50 \AA and Au having a thickness of 5000 \AA were sequentially deposited by vacuum evaporation. Then, unnecessary portions were removed by lifting-off, and the upper wiring 63 having a desired shape was formed (see Fig. 13(h)).

[0153] Through the foregoing steps, the lower wiring 62, the interlayer insulating layer 123, the upper wiring 63, the device electrodes 5 and 6 and the thin film 2 for forming the electron emitting portion were formed on the quartz substrate 1. Next, the example of constituting a display device using the electron source constructed in the above-described manner will be described with reference to Figs. 6 and 7.

[0154] The substrate 1 passed through the foregoing manufacturing steps

was installed on the rear plate 71. Then the face plate 76 (constructed by forming the fluorescent screen 61 and the metal back 75 in the inner surface of the glass substrate 73) was disposed 5 mm above the substrate 1 by interpolating the supporting frame 72. Flit glass was coated in the joined portions of the face plate 76, the supporting frame 72 and the rear plate 71, and sealed by baking in atmosphere or nitrogen atmosphere at a temperature of 400 to 500 °C for 10 min (Fig. 7).

[0155] At the same time, the rear plate 71 and the substrate 1 were fixed to each other by using flit glass. In Fig. 7, a reference numeral 61 denotes an electron emitting device; and 62 and 63 X-direction and Y-direction device wirings respectively.

[0156] The fluorescent screen 74 is made only of a fluorescent substance in the case of monochromatic displaying. However, in the described embodiment, the fluorescent substance of a stripe type was used, a black stripe was first formed, and each color fluorescent substance was coated on each gap portion to make the fluorescent screen 74. As a material for the black stripe, one containing graphite often used as a main component was used. A slurry method was used for coating the fluorescent substance on the glass substrate 73. In addition, the metal back 75 is generally provided in the inner surface side of the fluorescent screen 74. The metal back was made by forming a fluorescent screen, then smoothing (generally called filming) the inner side surface of the fluorescent screen, and vacuum-evaporating Al.

[0157] The face plate 76 may include a transparent electrode (not shown) provided in the outer surface side of the fluorescent screen 74 in order to further enhance the conductivity of the same. In the embodiment, however, the transparent electrode was omitted, since sufficient conductivity was provided only by the metal back. During the above-described sealing, since each fluorescent substance and each electron emitting device need to be in a corresponding relation in the case of color displaying, sufficient aligning was carried out.

[0158] Atmosphere in the glass container thus completed was discharged through the exhaust pipe (not shown) by the vacuum pump. After a sufficient vacuum degree was reached, a voltage was applied between the electrodes 5 and 6 of the electron emitting device 61 through the out-of

container terminals Dox1 to Doxm and Doy1 to Doyn, the thin film 2 for forming an electron emitting portion was subjected to forming, and thus an electron emitting portion 3 was formed.

[0159] A voltage waveform for the forming operation was the same as that shown in Fig. 4(b), and in the embodiment, the forming was executed in vacuum atmosphere of about 1×10^{-5} torr while T_1 was 1 msec., and T_2 was 10 msec. Then, evacuation was carried out to reach the vacuum degree of about 1×10^{-6} torr, the not-shown exhaust pipe was heated by a gas burner for welding, and the envelope was sealed. Lastly, to maintain the degree of vacuum after the sealing, a getter treatment was executed by the high-frequency heating method.

[0160] In the image display device of the invention thus competed, scanning modulating signals were applied through the out-of container terminals Dox1 to Doxm and Doy1 to Doyn to the respective electron emitting devices by not-shown signal generating means, thereby causing electron emission. Through the high voltage terminal Hv, a high voltage of several kV or higher was applied to the metal back 75 or the transparent electrode (not shown) to accelerate an electron beam. The electron beam was collided with the fluorescent screen 74 to excite/cause the fluorescent substance to emit a light. As a result, an image was displayed.

[0161] Embodiment 7

Fig. 14 is a block diagram showing an example of a display device constructed such that image information provided from various image information sources, for example for television broadcasting, can be displayed on a display panel using the SCE described above with reference to the embodiment 6 as an electron beam source.

[0162] In the drawing, a reference numeral 130 denotes a display panel; 131 a driving circuit for the display panel; 132 a display panel controller; 133 a multiplexer; 134 a decoder; 135 an I/O interface circuit; 136 a CPU; 137 an image generating circuit; 138, 139 and 140 image memory interface circuits; 141 an image input interface circuit; 142 and 143 TV signal receiving circuits; and 144 an input unit.

[0163] Needless to say, the display device reproduces a voice simultaneously with the displaying of a video when, for example like a television signal, a signal containing both video information and audio

information is received. However, description will be omitted of circuits for the reception, separation, reproduction, processing, storage, and so on, of audio information, and a speaker, which are not directly related to the features of the invention.

[164] Now, the functions of the respective units are described based on the flow of an image signal. First, the TV signal receiving circuit is a circuit for receiving a TV image signal transmitted by using a wireless transmission system such as radio waves, space optical communications or the like. No particular limitation is placed on the system of receiving a TV signal. Any one of available systems including an NTSC system, a PAL system, a SECAM system, and so on, can be used. A TV signal made of a larger number of scanning lines than these systems (e.g., so-called high definition TV, such as MUSE system) is a suitable signal source for taking the advantage of the display panel suited for increases in area and the number of pixels.

[0165] The TV signal received by the TV signal receiving circuit 143 is sent to the decoder 134. The TV signal receiving circuit 142 is a circuit for receiving a TV image signal transmitted by a wire transmission system such as a coaxial cable, an optical fiber or the like. However, as in the case of the TV signal receiving circuit 143, no particular limitation is placed on the system of receiving a TV signal. The TV signal received by this circuit is also sent to the decoder 134.

[0166] The image input interface circuit 141 is a circuit for capturing an image signal supplied from an image input device such as a TV camera, an image reading scanner or the like. The captured image signal is sent to the decoder 134. The image memory interface 140 is a circuit for capturing an image signal stored in a video tape recorder (abbreviated to VTR, hereinafter). The captured image signal is sent to the decoder 134.

[0167] The image memory interface circuit 139 is a circuit for capturing an image signal stored in a video disk, and the captured image signal is sent to the decoder 134. The image memory interface circuit 138 is a circuit for capturing an image signal from a device storing static image data like a so-called static image disk. The captured image signal is sent to the decoder 134.

[0168] The I/O interface circuit 135 is a circuit for connecting the display

device to an external computer, a computer network or an output device such as a printer or the like. The circuit 135 can not only transfer image data and character/graphic information but also transfer a control signal and numerical value data between the CPU 136 of the display device and an external unit when necessary.

[0169] The image generating circuit 137 is a circuit for generating image data for displaying based on image data and character/graphic information entered from the external unit through the I/O interface circuit 135 or image data and character/graphic information outputted from the CPU 136.

[0170] The described circuit incorporates a rewritable memory for accumulating, for example image data and character/graphic information, a read-only memory for storing an image pattern corresponding to each character code, and a circuit necessary for generating an image, e.g., a processor for image processing.

[0171] The image data for displaying, made by the circuit, is sent to the decoder 134. However, when necessary, the image data can be transmitted through the I/O interface circuit 135 to the external computer network or the printer.

[0172] The CPU 136 carries out work mainly regarding the control of the operation of the display device, and the selection/editing of a display image. To take an example, the CPU 136 outputs a control signal to the multiplexer 133, and properly selects and combines an image signal with another to be displayed on the display panel. In addition, in this case, the CPU 136 generates a control signal for the display panel controller 132 according to the image signal to be displayed, and properly controls the operation of the display device, e.g., a screen display frequency, a scanning method (e.g., interlacing or non-interlacing), the number of scanning lines on one screen, and so on.

[0173] Also, the CPU 136 directly outputs image data and character/graphic information to the image generating circuit 137, alternatively enters image data and character/graphic information through the I/O interface circuit 135 to the external computer or the memory by accessing the same. The CPU 136 may of course be engaged in work other than the above purposes. For example, the CPU 136 may be directly engaged in information processing like a personal computer or a word

processor. Alternatively, as described above, the CPU 136 may be connected through the I/O interface circuit 135 to the external computer network, and carry out work such as numerical value computing cooperatively with an external device.

[0174] The input unit 144 is used by a user to enter a command, a program or data to the CPU 136. For the input unit 144, for example, a keyboard, a mouse, a joystick, a barcode reader, a voice recognition device, and other various input devices can be used.

[0175] The decoder 134 is a circuit for reverse-converting various image signals entered from the circuit 137 or 143 into three primary color signals, or a luminance signal, an I signal and a Q signal. As indicated by a dotted line in the drawing, the decoder 134 should preferably include an image memory inside. The image memory is necessary for processing a TV signal during reverse-conversion, for example in the MUSE system.

[0176] Another reason for the installation of the image memory is that the displaying of a static image can be facilitated, or image processing/editing including image thinning, interpolation, expansion, reduction, synthesis, and so on, can be facilitated in cooperation with the image generating circuit 137 and the CPU 136.

[0177] The multiplexer 133 functions to properly select a display image based on the control signal entered by the CPU 136. Specifically, the multiplexer 133 selects a desired image signal from reverse-converted image signals entered from the decoder 134, and outputs the selected image signal to the driving circuit 131. In this case, by switching the image signals to select one within one screen display time, like a so-called multiscreen television set, one screen is divided into a plurality of regions, and different images can be displayed from region to region.

[0178] The display panel controller 132 is a circuit for controlling the operation of the driving circuit 131 based on the control signal entered from the CPU 136. The basic operation thereof includes, for example the outputting of a signal for controlling the operation sequence of a driving power source (not shown) for the display panel to the driving circuit 131, the outputting of a signal for controlling a screen display frequency or a scanning method (e.g. interlacing or non-interlacing) to the driving circuit 131, and so on. In some cases, the controller 132 may output a control

signal to the driving circuit 131, the signal regarding the adjustment of an image quality, such as the luminance, contrast, color tone, sharpness or the like of the display image.

[0179] The driving circuit 131 is a circuit for generating a driving signal to be applied to the display panel 130. The circuit 131 operates based on an image signal entered from the multiplexer 133 and a control signal entered from the display panel controller 132.

[0180] The functions of the respective units have been described. Because of the configuration illustrated in Fig. 14, in the display device, image information entered from various image information sources can be displayed on the display panel 130. Specifically, various image signals, e.g., for television broadcasting, are reverse-converted at the decoder 134, then properly selected at the multiplexer 133, and sent to the driving circuit 131.

[0181] On the other hand, the display controller 132 generates a control signal for controlling the operation of the driving circuit 131 according to an image signal to be displayed. The driving circuit 131 applies a driving signal to the display panel 130 based on the image signal and the control signal. In this way, the image is displayed on the display panel 130. These series of operations are controlled by the CPU 136 in an integrated manner.

[0182] In addition, in the display device, it is possible to not only display one selected from bits of information from the image memory incorporated in the decoder 134 and the image generating circuit 137 but also perform, for the image information to be displayed, image processing including expansion, reduction, rotation, movement, edge emphasis, thinning, interpolation, color conversion, aspect ratio changing of an image, and so on, and image editing including synthesis, deletion, connection, replacement, fitting, and so on. Although no particular reference was made in the description of the embodiments, as in the case of the image processing and the image editing, a dedicated circuit may be provided for processing and editing audio information.

[0183] Therefore, the display device can function as a display device for television broadcasting, a terminal device for television conference, an image editor for processing static and moving images, a computer terminal, a business terminal device such as a word processor, a game machine, and

so on, by one unit, and thus can be applied widely for industrial or private use.

[0184] Fig. 14 shows only an example of the configuration of the display device using the display panel with the SCE set as an electron beam source. Needless to say, the configuration is in no way limited to the above. For example, among the constituting elements of Fig. 14, the circuits of the functions unnecessary for an application purpose may be omitted.

[0185] Conversely, depending on purposes, more constituting elements may be added. For example, if the display device is applied as a TV telephone set, a television camera, a microphone, an illuminator, a transmitting/receiving circuit including a modem should preferably added to the constituting elements.

[0186] In the display device, especially since the display panel using the SCE as an electron beam source can be easily made thin, the depth of the display device can be reduced. In addition, since the display panel using the SCE as an electron beam source can have a large screen, high luminance and a good characteristic regarding an angle of visibility, the display device can display a very realistic and impressive image with good visibility.

[0187]

[Advantages of the Invention] As described above, according to the invention, in the surface conductive electron emitting device comprising the pair of opposing device electrodes formed on the substrate and the thin film having the electron emitting portion, the electron emitting portion is made of conductive fine particles such as metal or metal oxide and graphite or amorphous carbons, or a mixture thereof. Thus, the electron emitting device having a stable electron emission characteristic and high electron emission efficiency can be manufactured.

[0188] Moreover, in the electron source for emitting electrons according to an input signal, by arranging a plurality of the above electron emitting devices, the electron source can be stably manufactured with good yield. Also, the increased electron emission efficiency reduces the consumption of power, and the burdens of peripheral circuits or the like are reduced. Thus, an inexpensive device can be provided.

[0189] The image forming apparatus for forming an image based on an

input signal comprises at least an image forming member and the above electron source. Accordingly, a stably controlled electron emission characteristic and electron emission efficiency can be enhanced. For example, in the image forming apparatus using the fluorescent substance as an image forming member, a low-current, bright and high definition image forming apparatus, e.g., a color flat television set, can be realized.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] A configuration view showing an example of a manufacturing method of a planar surface conductive electron emitting device.

[Fig. 2] A process view showing an example of a manufacturing method of a surface conductive electron emitting device.

[Fig. 3] A configuration view schematically showing a measuring and evaluating device for measuring an electron emission characteristic of the surface conductive electron emitting device.

[Fig. 4] A view showing a voltage waveform of energizing processing for the surface conductive electron emitting device.

[Fig. 5] A view showing a basic characteristic of the surface conductive electron emitting device.

[Fig. 6] A configuration view showing an electron source composed of a simple matrix arrangement.

[Fig. 7] A basic configuration view showing an image forming apparatus.

[Fig. 8] A view illustrating a fluorescent screen.

[Fig. 9] A view showing a basic characteristic of the surface conductive electron emitting device.

[Fig. 10] A plan view schematically showing the electron source.

[Fig. 11] A sectional view taken on line A - A' of the electron source of Fig. 10.

[Fig. 12] A partial process view showing a former half of a manufacturing method of the electron source.

[Fig. 13] A partial process view showing a latter half of the manufacturing method of the electron source.

[Fig. 14] A block diagram showing an example of a display device.

[Fig. 15] A view schematically showing a configuration of a conventional electron emitting device.

[DESCRIPTION OF REFERENCE NUMERALS]

- 1 INSULATING SUBSTRATE
- 2 THIN FILM FOR FORMING ELECTRON EMITTING PORTION
- 3 ELECTRON EMITTING PORTION
- 4 THIN FILM 4 INCLUDING ELECTRON EMITTING PORTION
- 5, 6 DEVICE ELECTRODE
- 9 ELECTRON SOURCE SUBSTRATE
- 30, 32 AMMETER
- 31 POWER SOURCE
- 33 HIGH VOLTAGE POWER SOURCE
- 34 ANODE ELECTRODE
- 61 SCE INCLUDING ELECTRON EMITTING PORTION
- 62 X-DIRECTION WIRING (LOWE WIRING)
- 63 Y-DIRECTION WIRING (UPPER WIRING)
- 71 REAR PLATE
- 72 SUPPORTING FRAME
- 73 GLASS SUBSTRATE
- 74 FLUORESCENT SCREEN
- 75 METAL BACK
- 76 FACE PLATE
- 78 ENVELOPE
- 81 BLACK CONDUCTIVE MATERIAL
- 82 FLUORESCENT SUBSTANCE
- 121 Cr FILM
- 122 FILM MADE OF PdO AND POLYIMIDE
- 123 INTERLAYER INSULATING LAYER
- 124 OPENING PORTION
- 130 DISPLAY PANEL
- 131 DRIVING CIRCUIT
- 132 DISPLAY PANEL CONTROLLER
- 133 MULTIPLEXER
- 134 DECODER
- 135 I/O INTERFACE CIRCUIT
- 136 CPU
- 137 IMAGE GENERATING CIRCUIT
- 138, 139, 140 IMAGE MEMORY INTERFACE CIRCUIT

- 141 IMAGE INPUT INTERFACE CIRCUIT
- 142, 143 TV SIGNAL RECEIVING CIRCUIT
- 144 INPUT UNIT